A COMPARATIVE STUDY OF SCHEDULES FOR STANDING WATCHES ABOARD SUBMARINES BASED ON BODY TEMPERATURE CYCLES

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Naval Medical Research Institute
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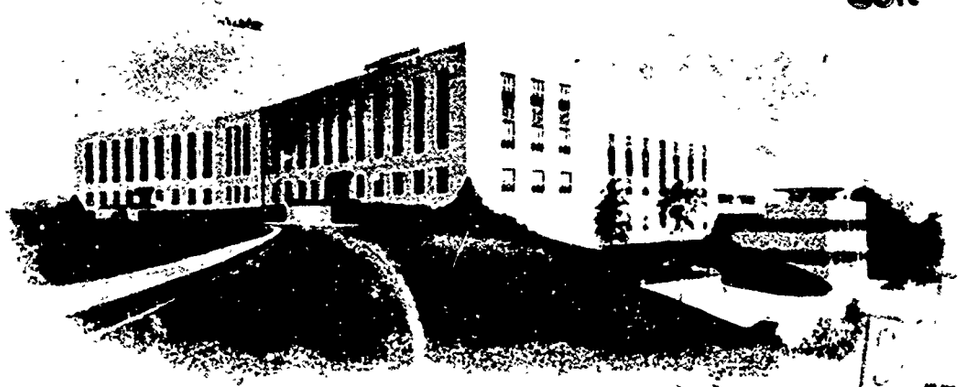

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Project NM 004 003 Report No. 1

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ABSTRACT

A new watch schedule has been proposed for use on naval vessels at sea. This schedule requires three watches of 3-, 3- and 2 hour durations by each section of the crew, and provides a continuous period off duty of 10 to 12 hours.

This schedule has been compared with the present system of four-hour watches separated by eight hours off duty (4 on - 8 off schedule). Comparisons have been made during two short cruises and during two long simulated war patrols. The rapidity with which the men adapted to the schedules was determined by means of oral temperature cycles, which also afford an indication of the alertness and efficiency of men on watch.

On the basis of the body temperature studies, the proposed schedule was found to be a definite improvement over the present one. Subjective reactions to the proposed schedule were obtained from the men, and suggestions for overcoming the chief sources of complaint are made.

INTRODUCTION

To maintain a constant watch aboard ship, naval personnel customarily are divided into three sections, one section being on duty at a time. Traditionally, a section works four hours and is off duty eight hours, constituting two 12-hour cycles in each day A section is often changed from one set of watch-hours to another Although this schedule is routine, others which appear better suited to the requirements of a particular job are used freely

This present schedule of watches seems in conflict with physiological data. Man has relatively fixed physioiogical rhythms, such as the diurnal temperature cycle, which are not readily changeable. When these rhythms are not in synchrony with his sleeping and waking cycle it is probable that his efficiency and his feeling of well being are reduced and his rest disturbed. The practice of rotating watches disregards this fact. Furthermore, the change from a 24-hour cycle, such as is followed on shore, to a 12-hour cycle aboard ship seems unnecessary and likely to create difficulties. In addition, the present watch schedule does not allow eight continous hours of sleep, which may be another disadvantage. Watch schedules should be so constructed that the usual cycle of activity or alertness during the day, alternating with sleep at night, might be replaced by a program providing for maintained alertness of watch personnel throughout the 24-hour period. It is essential that every watch stander be fully awake before he comes on watch and that he remain so throughout his watch.

On the basis of these and other considerations, N. Kleitman, as a member of the Committee on Undersea Warfare of the National Research Council, undertook a study of the present schedule used aboard the submarine USS DOGFISH. On a submarine the alternation of day and night, which is one of the most important factors in determining the customary sleep-wakefulness cycle, can be almost entirely eliminated For this reason, a submarine constitutes an excellent situation for the study of rhythms other than the normal shore cycle. Kleitman concluded from his observations that, "The survey of the routine of living on a typical submarine underway revealed an incomplete adjustment of the personnel to the requirement of an even degree of alertness during the 24-hour cycle of day and night and an absence of conditions conducive to such an adjustment." He further proposed a schedule based on a 24-hour cycle. The regular (4 on - 8 off) schedule and Kleitman's proposed schedule are shown in figures 1 and 2.

Since the nine meals a day proposed by Kleitman seem excessive for the galley, another schedule (fig. 3) again based on a 24-hour cycle, and incorporating many of Kleitman's suggestions, was drawn up. This new schedule proposes three watches of 3-, 3- and 2-hour durations. The objectives of the new schedule are

a. Increased alertness and efficiency as a result of adjustment of working hours so that maximum body temperatures might more easily coincide with them.

b. Provision for 10-12 continuous hours off duty, during which a long uninterrupted sleep may be secured.

c. Watches of shorter duration, still providing for a total of eight hours' watch for each man.

d. A schedule so nearly impartial that the watch periods might be fixed for each section throughout the cruise

e. A hot meal offered the men on each section before beginning their first watch of the day.

f. A dinner hour so arranged as to make it possible for the men of all sections to eat this principal and best-balanced meal of the day without disrupting sleep or breaking into a watch period.

Accordingly, this schedule assigned each section one two-hour and two three-hour watches, followed by long off-duty periods, varying from 10 to 12 hours. It was arranged to serve a fourth meal in each 24 hours, and the meal hours were then arranged as in figure 3. Breakfast, dinner and supper were unchanged except for the hour. The new meal consisted of soup, sandwiches and coffee, with pastry occasionally. The work reported here represents an attempt at objective evaluation of the schedule shown in figure.3 as compared with the present schedule of two four-hour watches each day.

METHOD

It has been known for a long time that there is a diurnal temperature cycle, with the maximum occurring during the hours of wakefulness and the minimum during sleep. When the pattern of one's activities and sleep are changed, the temperature does not immediately follow the activities, but if the new pattern is maintained for sometime the temperature cycle usually conforms to it. The initial failure of the temperature cycle to conform to the new activity pattern is probably indicative of the resistance of the body rhythms to the new regime, and one can legitimately expect efficiency of operation to be lower during the period when the temperature and activity patterns are out of synchrony than when they are in it. This judgment is supported by the introspection of people who have changed their sleep and activity habits.

In addition, body temperature has been found by Kleitman (1,2) to be related to the speed and accuracy of performance of a number of tasks, such as card-sorting, mirror-drawing, code transcription, multiplication and reaction time. The published data do not permit one to say how large this correlation is, but one would judge it to be high, despite the possibility of such factors as motivation and emotions affecting one

of the variables without changing the other

For the reasons given above, and because of the simplicity of the measurement, temperature was chosen as the means of comparing the adjustment of the men to the present and the proposed schedules.

Four submarine cruises were made. The temperatures were taken by the members of the crew themselves when they were awake, and by a medical officer or a hospital corpsman when the men were asleep. Each man either demonstrated his ability to use a clinical thermometer, or was instructed in the use of it. As a check, the temperature measurements were frequently repeated by one of the observers in the course of the cruise. Each man was asked to keep a log of his major activities including actual times going on and off watch, extra work periods, meal hours, between meal snacks, recreation, rest and sleep. The oral temperatures were taken and entered in this log at intervals of two hours. The sleep temperatures were entered in the logs by the observers at the end of the cruise.

The men were selected on the basis of an informal interview. An attempt was made in the interview to establish an interest in the study without entering into any controversy and without comment on any expected findings. The subjects were chosen from those indicating an intelligent interest in the study and willingness to perform the required tasks.

The number of men taking part in the study are indicated in table 1, which also includes the duration of the cruises and the type of schedule maintained on each cruise.

Table 1. - Type, duration and number of men participating in four cruises.

Cruise No.	Type	Duration	Number of men		
			Sect. I	Sect. II	Sect. III
I	Present	3½ days	6	5	6
II	Proposed	4 days	6	4	5
III	Present	19 days	10	11	8
IV	Proposed	21 days	8	10	10

Cruises I and II were short training cruises. Cruises III and IV were simulated war-time patrols. During the latter two cruises the men lived their respective routines for three weeks without interruption from shore leave or "dogging" the watches.

At the end of cruises II and IV the subjects were asked to express their preferences for the standard and proposed schedules and were also asked to give the reasons for their preferences.

It should be stated that the records are not complete for every day of the cruise or for every section of the crew Since the breakage of thermometers considerably exceeded our expectations, it became necessary to shift the available thermometers to the sections adapting most slowly to the schedule

RESULTS

Adaptation.- The rapidity with which the work patterns and the temperature cycle synchronize one with the other can be used as a basis for comparison of the two schedules.

An indication that the members of the crew adapt more readily to the 3-3-2 schedule than to the present one is found in figure 4.

The temperatures of the men of sections II and III on the 3-3-2 schedule have shifted towards the hours of their work with which they should ultimately coincide. The temperatures of the men on the 4 on-8 off schedule (fig. 4) at this stage do not show this shift These temperatures, however, are the averages of only three days on each schedule.

On longer cruises, each lasting approximately three weeks, the indications of this earlier work were confirmed. Figure 5 shows successive daily temperatures of each of the three sections for both schedules. On the 3-3-2 schedule the men of sections I and II had adapted very early in the cruise and the men of section III had done so by the twelfth day. The men on the 4 on - 8 off schedule were not well adapted even on the eighteenth day of the cruise.

A further indication that adaptation has not taken place as quickly on the 4 on - 8 off schedule as on the 3-3-2 is presented in figure 6. The men on the present schedule have a minor temperature peak followed by a larger one. If the men were completely adapted to the 12-hour cycle, the two peaks would be of equal magnitude. A 24-hour cycle remains with two 12-hour cycles superimposed on it. Continued duty on the present schedule of watches may never bring about complete adaptation because the meal hours and recreation periods still conform to the routine followed by people who live according to the conventional 24-hour cycle.

Relative efficiency.- The two schedules can also be compared on the basis of the assumption that efficiency is directly related to body temperature On this assumption, the ideal watch schedule would be one in which the temperatures of the men on watch would remain at a high constant level within the normal range. The temperatures of the men on watch during the final days of the cruise have been averaged and are presented in figure 7. The men standing watches on the 3-3-2 schedule have an approximately constant temperature well above 98° F. during all their watch hours, presumably indicating a high constant state of efficiency. On the other hand, the men standing watch on the 4 on - 8 off schedule had temperatures below 98° F. approximately one-half of their watch hours. These differences are statistically significant.

Similarly the men on the proposed schedule had lower temperatures while they were asleep. These averages, which again were obtained from the final days of the cruise, are shown in figure 8. Again the differences are statistically significant.

The proposed schedule is presumably superior to the present schedule both in terms of efficiency and rest.

Modifiability of the diurnal rhythm. - Environmental temperature.- In order to ascertain the effect of environmental temperature the oral temperatures of men on lookout and helm watches were selected and averaged. Similarly, the temperatures of men on engine room watches were selected and averaged. The temperatures of the environment in which the former group worked ranged from 24° F. to 55° F. while that for the latter group never fell below 70° F. and frequently ranged as high as 90.0° F. The average watch temperatures for men in these widely contrasting environments (fig. 9) are strikingly similar. In general, they fall within the 98.0° to 98.5° F. range characteristic of the overall averages for watch temperatures. This gives further evidence that the diurnal body temperature cycle is almost completely independent of environmental temperatures (3).

Activity or sleep at unusual hours. - An opportunity to determine the changes in the temperature cycle as a result of activity at a time usually devoted to sleeping was afforded on cruises I and II. Extra work of repair and maintenance, "clean-up ship", and maneuvers that required all hands, made it necessary to call men to activity during their usual sleep period. The temperature level of the men whose sleep was interrupted was raised an average of 0.9 degree.

Likewise, when sleep occasionally occurred during the usual waking hours, a fall in temperature of approximately one degree followed. However, the lower temperature levels characteristic of regular sleep periods were not reached.

Entertainment. - In each set of observations it has been noted that a strikingly large number of high temperatures was associated with activities such as card-playing, reading and attendance at movies. The circumstances under which these observations were made preclude any definitive statement of cause and effect. Whether the men engage in such recreational activities only when their temperatures are high, or whether their temperatures rise because they are engaged in such activities, certainly the two are closely related. Games, reading, and movie attendance are invariably accompanied by temperatures as high as, or higher than, the highest values attained during periods of work or watch.

Individual resistance. It is common knowledge that there are marked differences in the ability of individuals to adapt to changes in their routine of living. It was not surprising then that adaptation

to the new schedule should vary from the extreme of two men whose temperature levels did not come to parallel their activity schedules in 20 days on the schedule to the two men who made a most striking adjustment within 36 hours. These latter two (both in section II) now had their temperature peaks six to eight hours later, and their lows two to four hours later with an average range of 2.2° in one case and 2.5° in the other.

Subjective responses.- The most frequently criticized feature of the 4 on - 8 off schedule was the practice of "dogging" the watches. This procedure is apparently considered to be a necessary evil, practiced because some men strongly dislike certain watch hours and insist that the watches be rotated.

At the end of cruise II, an attempt was made to get the reaction of the men to the new schedule. Thirty-five men were asked to comment, 20 of these having participated in the temperature study. Only three men expressed unqualified opposition to the new schedule. This opposition was based on (a) inability to sleep during the day, and (b) objection to any change. All of the men of section I who were asked their opinion were well pleased with the new schedule and preferred it to the 4 on - 8 off schedule even for short cruises. The remainder of the men almost uniformly gave qualified approval to the new schedule. They heartily endorsed the three short watches in preference to two longer ones and they liked the idea of one long sleep period. They were indifferent to the changes in the meal hours but liked the midnight meal. They all felt that they were not on the schedule long enough to become accustomed to it and that it required too much adjustment to be suited to short cruises of the type just made. All said that they believed it would be superior to the 4 on - 8 off schedule during longer patrols.

At the end of cruise IV the men were asked to point out the features that they liked or disliked in the new schedule and to state whether or not they would prefer to follow it on another similar patrol. Their comments were summarized below:

Likes

Regular hours of sleep	7
Able to get more sleep	9
Shorter watches not so tiresome and less monotonous	5
Time "goes faster"	5
Less troubled by sleepiness on watch	2
More opportunity to do things while off duty	5
More normal routine--more like shore life	1

Dislikes

Don't get enough sleep	7
Meal hours not convenient: meals not in usual order	3
Day too complicated	1
Broken sleep periods	4
Don't like working at night	2
Not enough time off	1
"Clean up ship" always at the same hours	2
"Too many people up at once" causing the air to be foul	1
Upsets regular habits	2
Makes days seem longer	2
Sleepier on watch	1
Too many disturbances during sleep hours	3
Awake too long at a time	2

The men stated whether they would prefer the new schedule for similar patrols as follows.

Section	For	Against	Undecided
I	15	2	2
II	11	7	1
III	4	14	3
Total	30	23	6

DISCUSSION

The present 4 on - 8 off schedule is essentially a 12-hour cycle of work and rest. However, the meal hours and recreation periods still conform to the routine followed by people who live according to the conventional 24-hour cycle. Throughout a 12-hour period no meals are served, although the watches must be maintained. Organized recreation is customarily provided during the evening hours only. Activities other than watch are concentrated within the daylight hours, making sleep at this time difficult. These factors play a significant role in the failure of these men to adapt to a 12-hour cycle (fig. 5). Moreover, experiments in the past have shown that adaptation to a 12-hour cycle of sleep-wakefulness is more difficult than that to longer cycles (4).

The new schedule provides a 24-hour cycle of work, sleep, meals and recreation. Adaptation depends only upon a shift in this cycle eight hours earlier for one section and eight hours later for the other. Comparable shifts in the diurnal rhythm are frequently accomplished by people passing through successive time-belts. Lindhard (5) has reported complete adaptation to a 12-hour shift of the cycle in a group of man who spent the winter in Greenland. His study included body temperature measurements which showed a compensatory reversal of the diurnal curve.

In community life, the individual adheres to a conventional pattern of work, sleep, meals and recreation at customary times. Most individuals strongly resist any marked change in their habits and routine of living. This resistance-to-change presents one of the most serious obstacles to the willing acceptance of a new schedule and convinces one of the importance of this factor. Although the new schedule may appear to offer numerous advantages when considered objectively, its ultimate success will depend upon the approval of the personnel who must live by it. In order to win the wholehearted approval of the men it is extremely important that work and sleep hours of the three sections be impartially distributed. Meals should be equally convenient for all, and similar recreation available to all. Every effort should be made to avoid the customary association of work and sleep hours with day and night, respectively. Each of the three sections should be able to follow a completely independent 24-hour cycle.

In administration of the new schedule it is necessary to keep in mind certain everyday events which, if left unchanged, will exert a marked psychological effect on men. One of the most important of these is the time at which organized recreation is provided. For example, if movies are to be shown they must be shown at least twice, and at different times, so that no favoritism is shown to any section. Another point to be kept in mind is the hour at which "clean up ship" is to be carried out. This should coincide with that period of the day when the greatest number of men would ordinarily be awake. Probably the best time is 1400 - 1600. A third factor of importance is the repair and maintenance work necessarily performed outside watch hours. This work should be allocated to the various sections impartially and not saved for the night watch. If there are to be all-hands maneuvers or drills at arbitrarily determined times, these times should be at random throughout the 24-hours.

The midnight meal should not be neglected, and at least one component of the meal should be hot and freshly prepared. If at all practicable, all personnel, including the commissioned officers, should adhere to the new schedule; if any portion of the crew is on a schedule based on shore routine, those who have working hours other than the customary ones will be made acutely aware of it. Last, but not least, the chief of the boat should be a member of some section other than the first, preferably the

third, in order that he may be completely aware of the problems incident to adaptation and have no tendency to initiate, at daytime hours only, those tasks which are his responsibility.

If it is still felt by the men that there are inequalities in the working day, then these inequalities might be rotated at intervals. For example, the schedule of meal hours might be reversed so that the best meal of the day would be served at 2400, breakfast at 1900, etc. School-of-the-boat might be conducted at 2200 or 0200 Clean-up-ship might be held at 2300. In this way the most difficult adjustment, that to a particular sleep-wakefulness cycle, need be made only at the beginning of the cruise, minor inequalities in daily routine would fall to each section in turn

SUMMARY AND CONCLUSIONS

During a series of four submarine cruises, records were made of activity and body temperature variations in representative groups of men On two of these cruises the 4 on - 8 off schedule was followed. On the other two cruises trial was made of a new schedule, based upon physiological principles, with three watch periods of 3-3-2 hours' duration.

A comparison of the proposed 3-3-2 schedule of watches with the watch schedule most used at present has shown that from the standpoint of sound physiology the proposed schedule is superior Specifically:

a. The body temperatures found in men on watch under the 3-3-2 schedule are consistently higher than those found at comparable times under the 4 on - 8 off schedule Maintenance of higher temperatures during watch periods is beleived to indicate the existence of a greater degree of alertness at these times.

b. In men on the 4 on - 8 off schedule, relatively low temperature levels were frequently found among men on watch between 0200 and 1200 even after 18 days on that schedule. This was never true of men on the 3-3-2 schedule after the twelfth day.

c. More rapid and more complete adaptation is found in men on the new schedule, as indicated by the earlier and closer conformation of the body temperature rhythm to the cycle of sleep and wakefulness. Significantly lower sleep temperatures and higher watch temperatures are exhibited by men adapted to the 3-3-2 schedule.

In individuals following a regular routine there was observed a markedly constant rise and fall of body temperature correlated with wakefulness and sleep, respectively. This temperature curve was modified as follows:

a. Entertainment such as movies, games and reading, which probably resulted in some degree of excitement, was invariably accompanied by higher than average temperatures.

b. Environmental temperature was shown to have had little or no influence on the form of the diurnal temperature curves.

c. Activity at a time usually devoted to sleep raised the body temperature appr. imately 0 9 degree but the high level characteristic of usual activity periods was not attained. Similarily, sleep at a time usually given over to activity caused a depression of the temperature of about one degree, but the low levels of usual sleep periods were not reached.

In general, the new schedule won the qualified approval of a majority of the men. Most were of the opinion that for long patrols it would be an improvement over the watch schedules followed heretofore. The men standing watch between 0400 and 0700 offered the greatest number of objections. They felt that they were required to work and sleep at the most undesirable times of the day. A large number of their objections can be attributed only to the effort of overcoming inertia involved in any change in the habits and routine of living.

Suggestions are offered which should lead to improvement in the operation of the proposed schedule in any future trials.

ACKNOWLEDGMENTS

The authors wish to thank the officers and men of the USS CUBERA, the USS TUSK and the USS SIRAGO for their cooperation in this study. Appreciation is due particularly to those men who participated in the temperature measurements, and to the commanding officers, Cmdr. Raymond Berthrong of the SIRAGO, Lt Cmdr. H. E. Davey of the CUBERA and Cmdr. E. F. Gagliotta of the TUSK, whose assistance and consideration were essential to the success of the work The collaboration of Lt. (jg) Thomas Ritch, MCR, USNR in collecting the temperature records of men following the 4 on - 8 off schedule during simulated war patrol is gratefully acknowledged Dr Ritch contributed most generously of his time and energy, and the records he collected form the bulk of our "control"data. For their considerable assistance in the tedious job of taking temperatures "around the clock" appreciation is due Hospitalman Chief H. M. Seese and Hospitalman Chief L. J. Lindhe. The authors wish to acknowledge the valuable guidance afforded by Captain Thomas Willmon, Chief Medical Officer at the New London Submarine Base. Appreciation is accorded Mr. Thomas Connor for his valuable and conscientious help in preparing the illustrations. The authors gratefully acknowledge the advice and valuable constructive criticism of Dr. John.P . Flynn, director of the Psychology and Statistics Facility at the Naval Medical Research Institute, under whose guidance the records were analyzed and the manuscript prepared.

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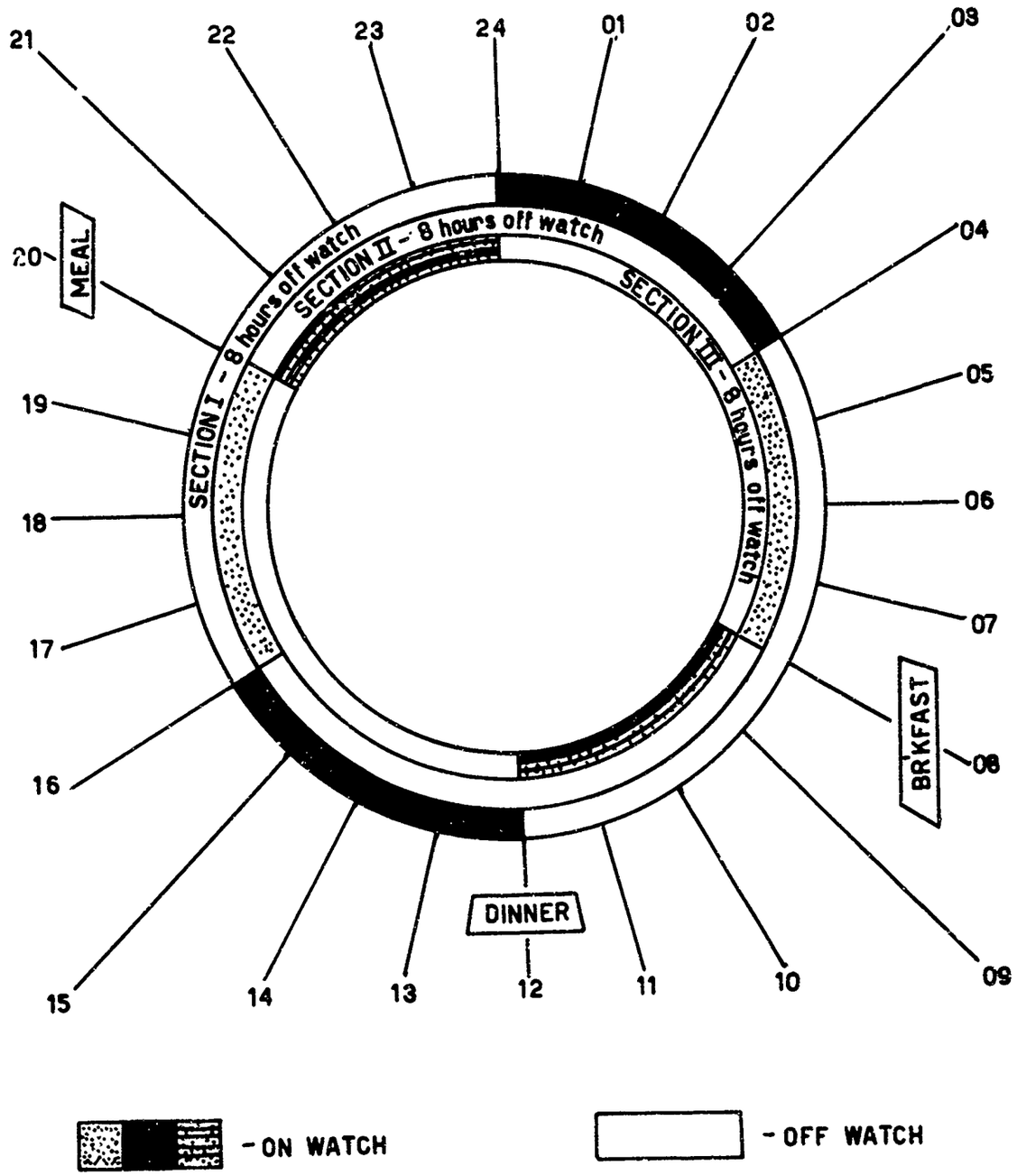


Figure 1.- Present Schedule (4on - 8off)

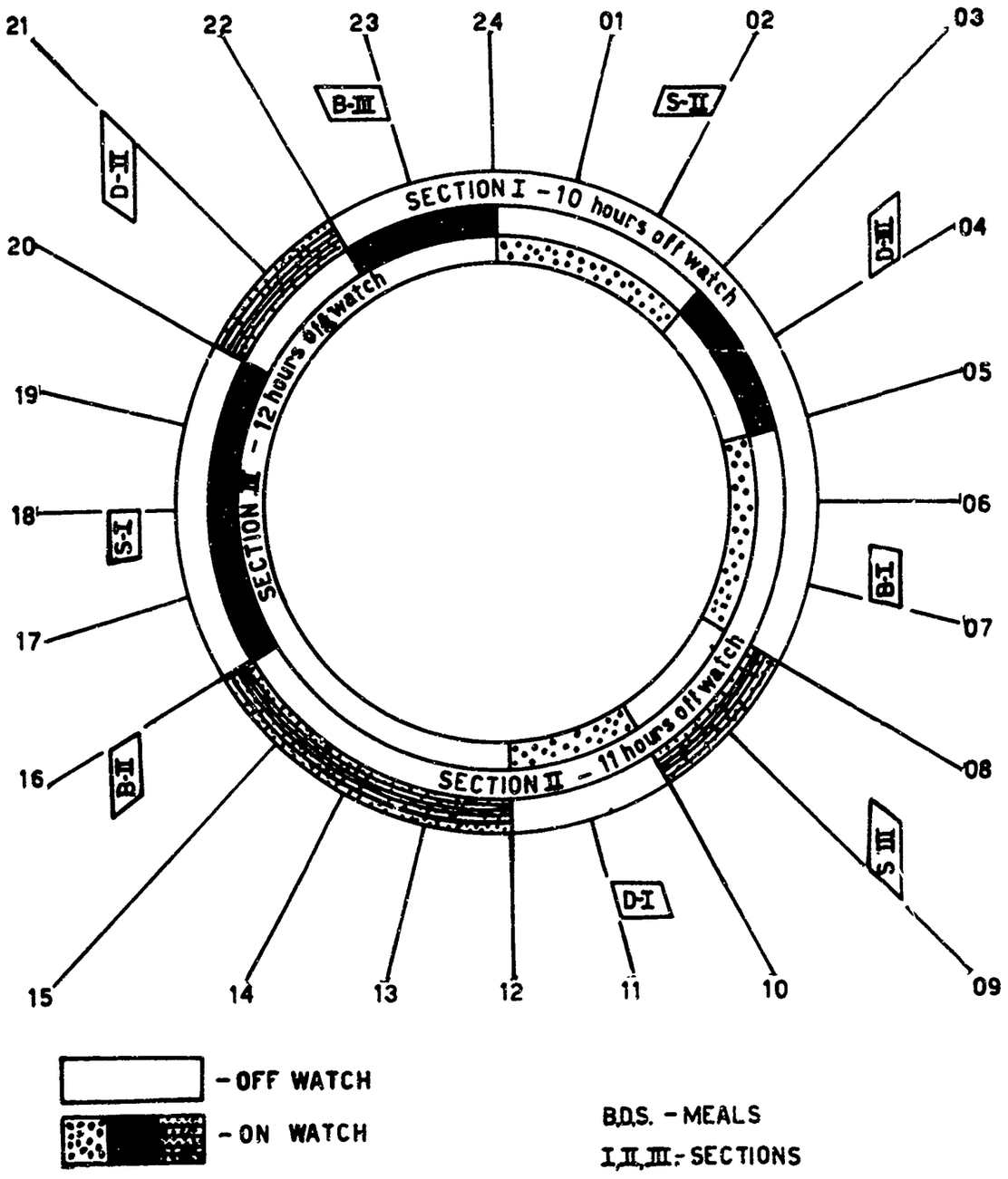


Figure 2.- Schedule proposed by Kleitman.

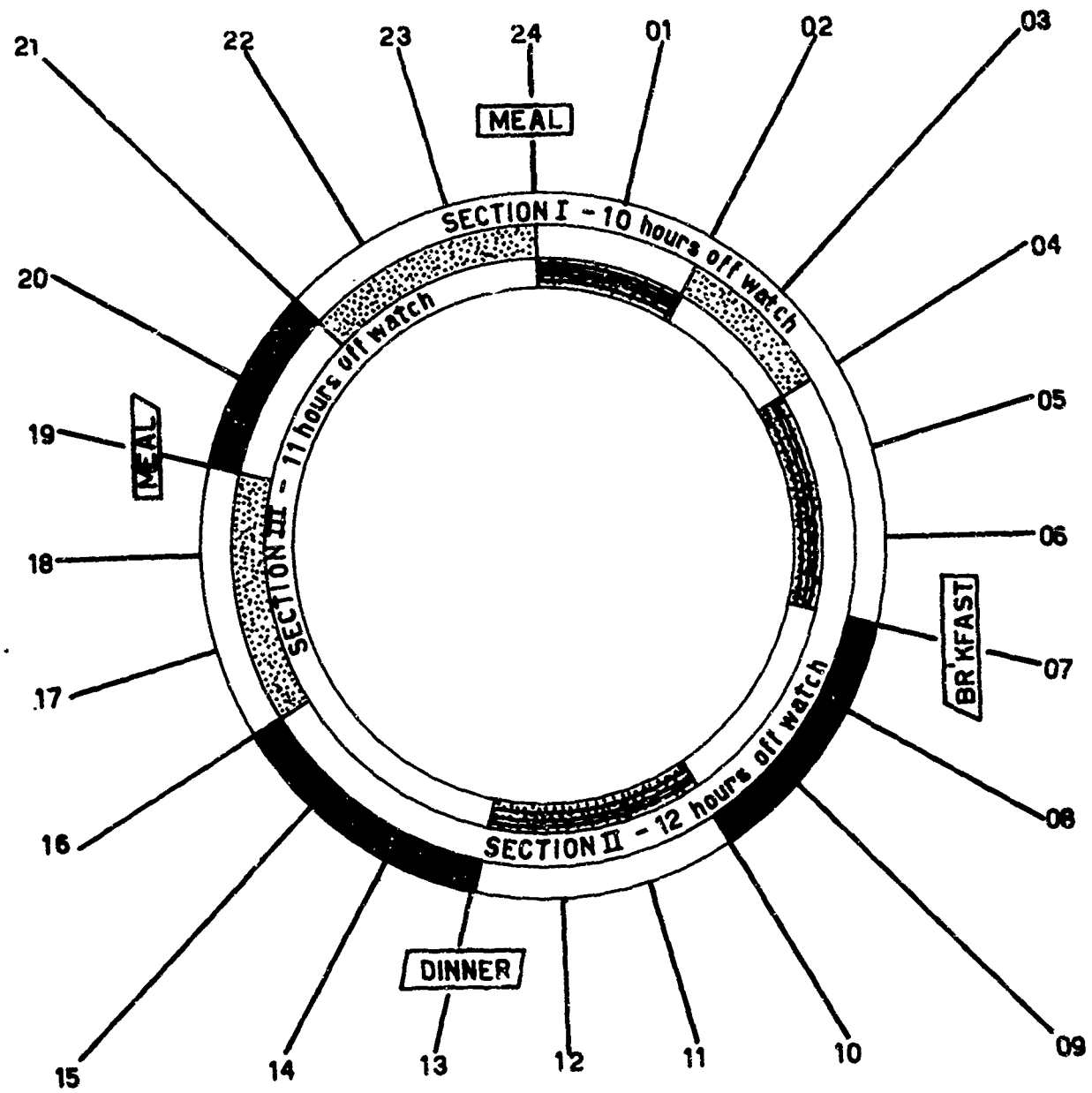


Figure 3.- Schedule proposed by Utterback and Ludwig(3-3-2)

Figure 4.- Comparison of average temperatures of each section for three days on the present schedule (4 on - 8 off) with the proposed schedule (3-3-2). The watch periods of the various sections are indicated by the double lines on the temperature curves and by the blocks below the curves.

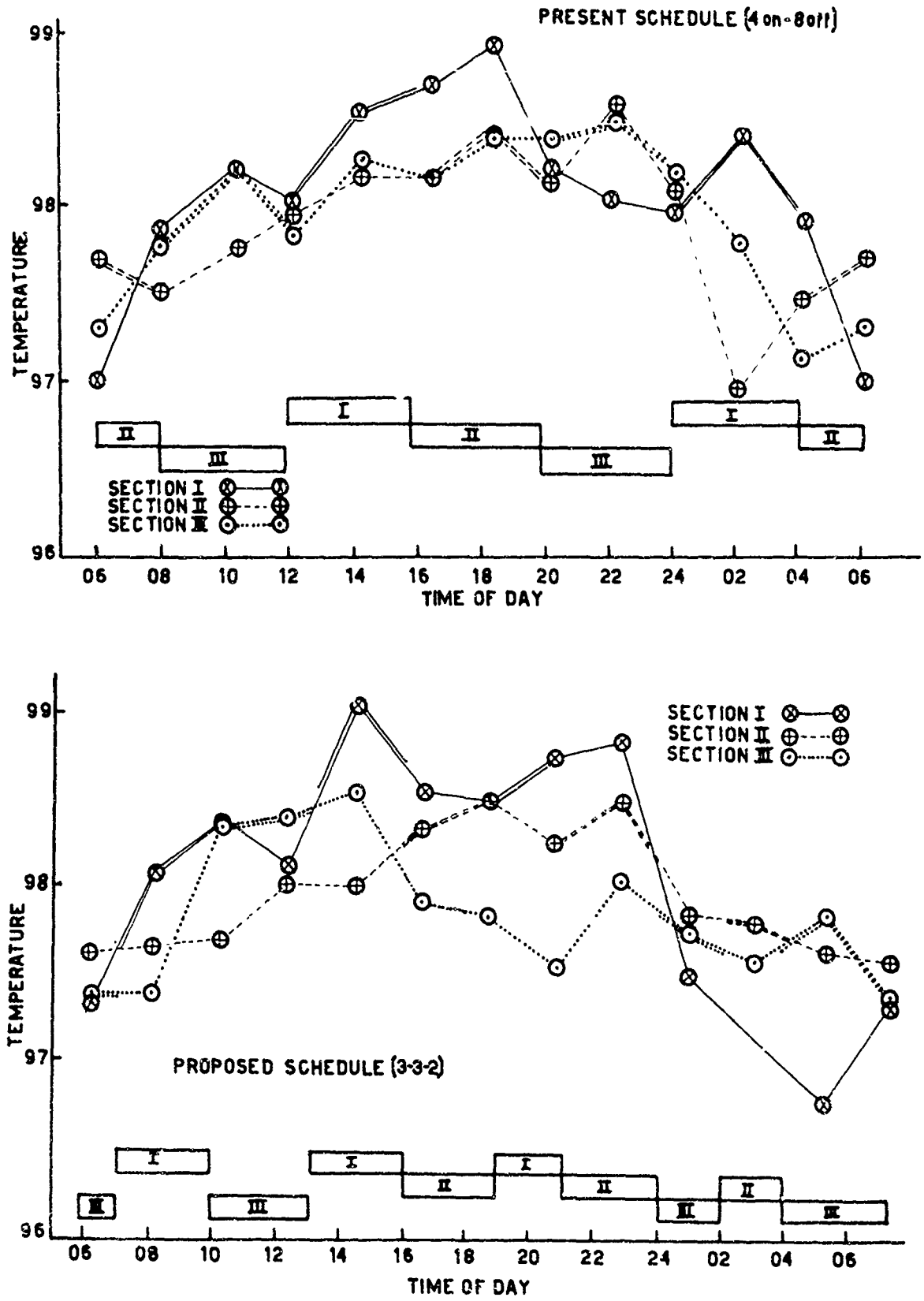

PRESENT SCHEDULE (4 on-8 off)
TEMPERATURE
99
98
97
96
06
08
10
12
14
16
18
20
22
24
02
04
06
TIME OF DAY
I
II
III
SECTION I
SECTION II
SECTION III
PROPOSED SCHEDULE (3-3-2)

Figure 4.

Figure 5 - Comparison of successive daily temperature averages for each of the three sections on the present schedule (4 on - 8 off) with the proposed schedule (3-3-2). The shaded areas indicate the watch periods. The number of the day on each cruise is indicated above the curves.

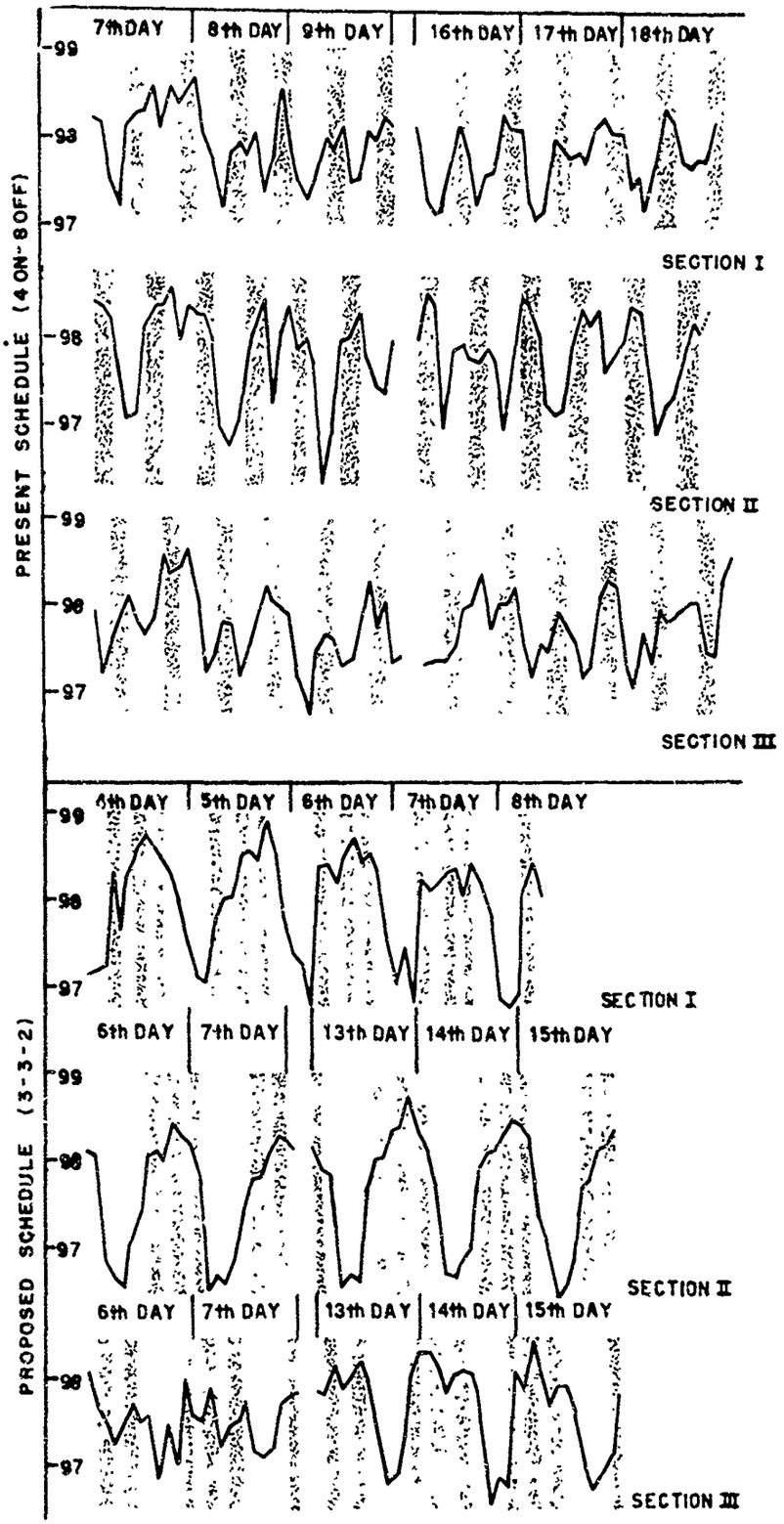
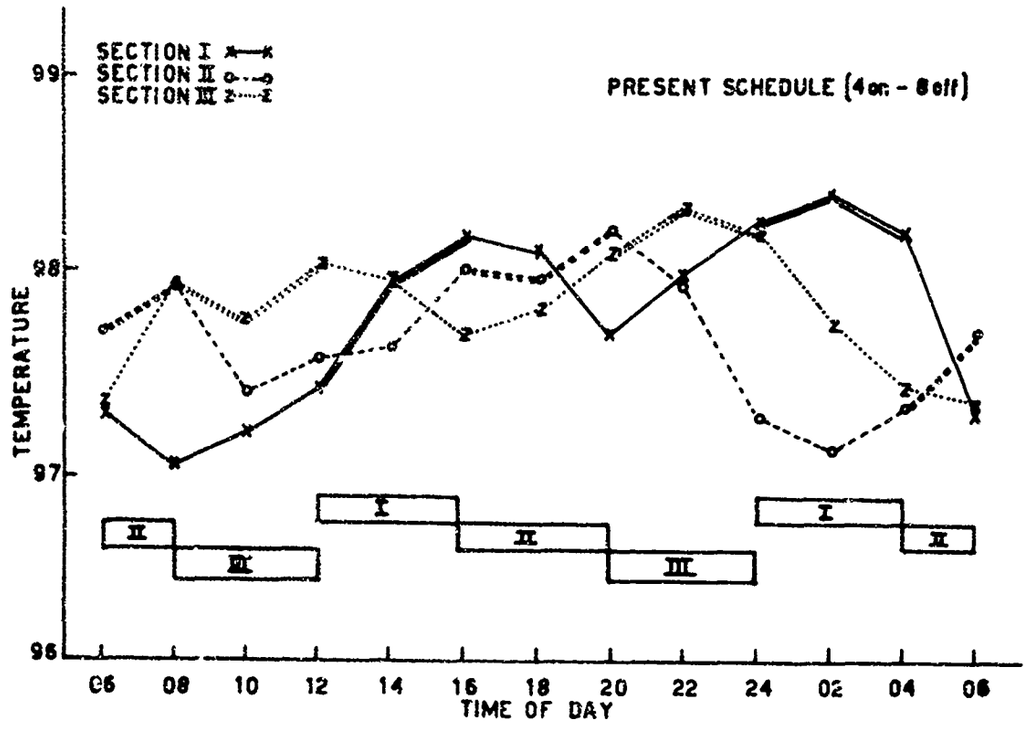

PRESENT SCHEDULE (4 ON-8 OFF)
7th DAY
8th DAY
9th DAY
16th DAY
17th DAY
18th DAY
99
98
97
SECTION I
SECTION II
SECTION III
PROPOSED SCHEDULE (3-3-2)
4th DAY
5th DAY
6th DAY
7th DAY
8th DAY
6th DAY
7th DAY
13th DAY
14th DAY
15th DAY

Figure 5.

Figure 6.- Comparison of average temperatures of each section for seven days on the present schedule (4 on - 8 off), with the proposed schedule (3-3-2). The watch periods of the various sections are indicated by the double lines on the temperature curves and by the blocks below the curves.


SECTION I
SECTION II
SECTION III
PRESENT SCHEDULE (4 on - 8 off)
TEMPERATURE
99
98
97
96
06 08 10 12 14 16 18 20 22 24 02 04 06
TIME OF DAY

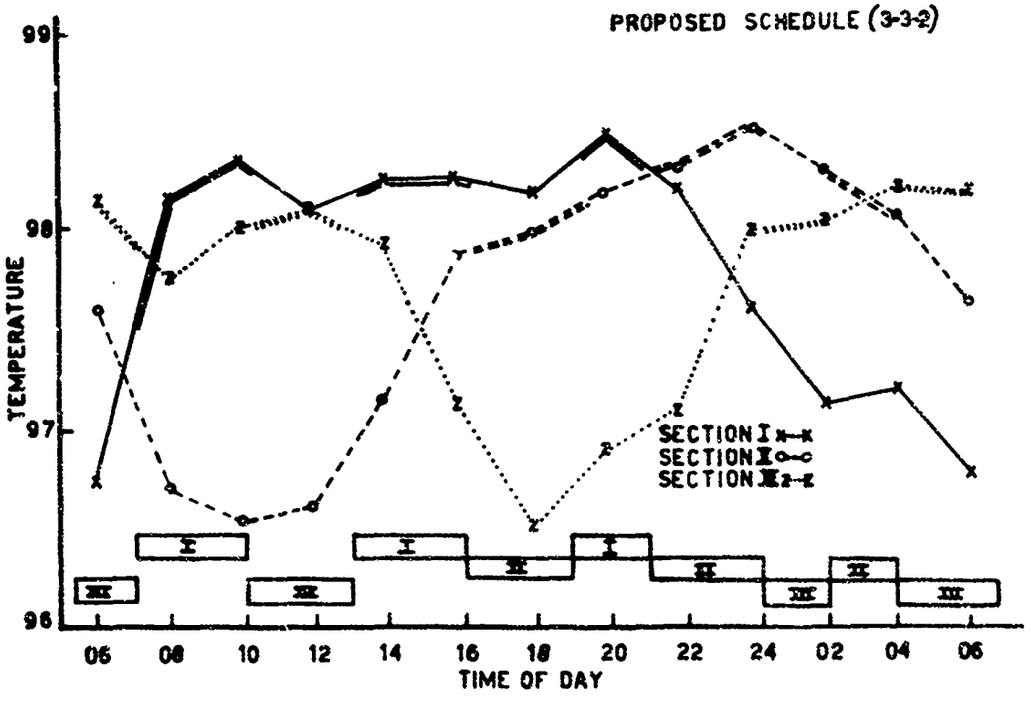

PROPOSED SCHEDULE (3-3-2)
TEMPERATURE
99
98
97
96
SECTION I
SECTION II
SECTION III
06 08 10 12 14 16 18 20 22 24 02 04 06
TIME OF DAY

Figure 6.-

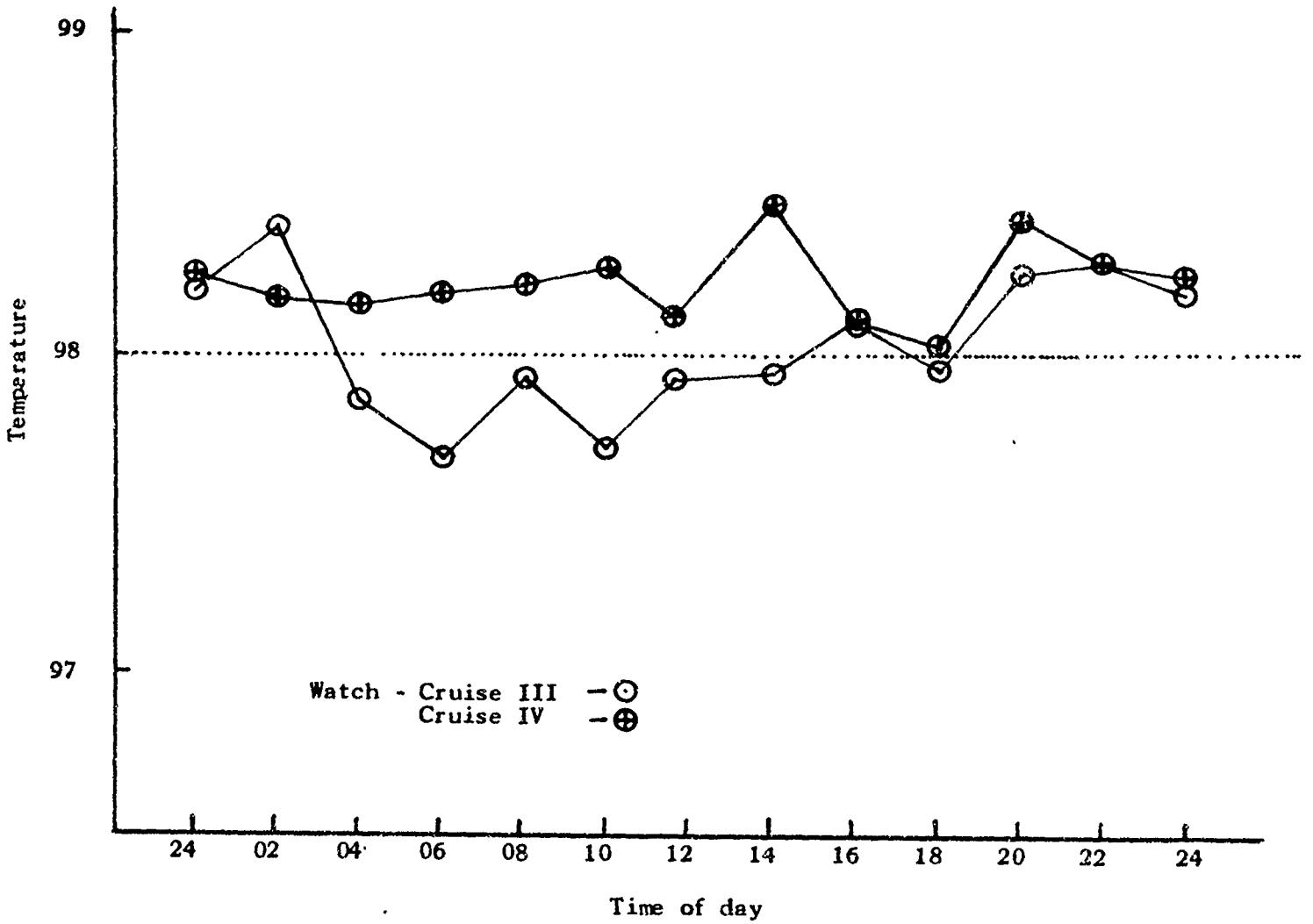


Figure 7.- Averages of temperatures of men on watch throughout each 24-hour period during the final days of cruises III and IV. On cruise III, the present schedule (4 on - 8 off) was followed, while the proposed schedule (3-3-2) was followed on cruise IV.

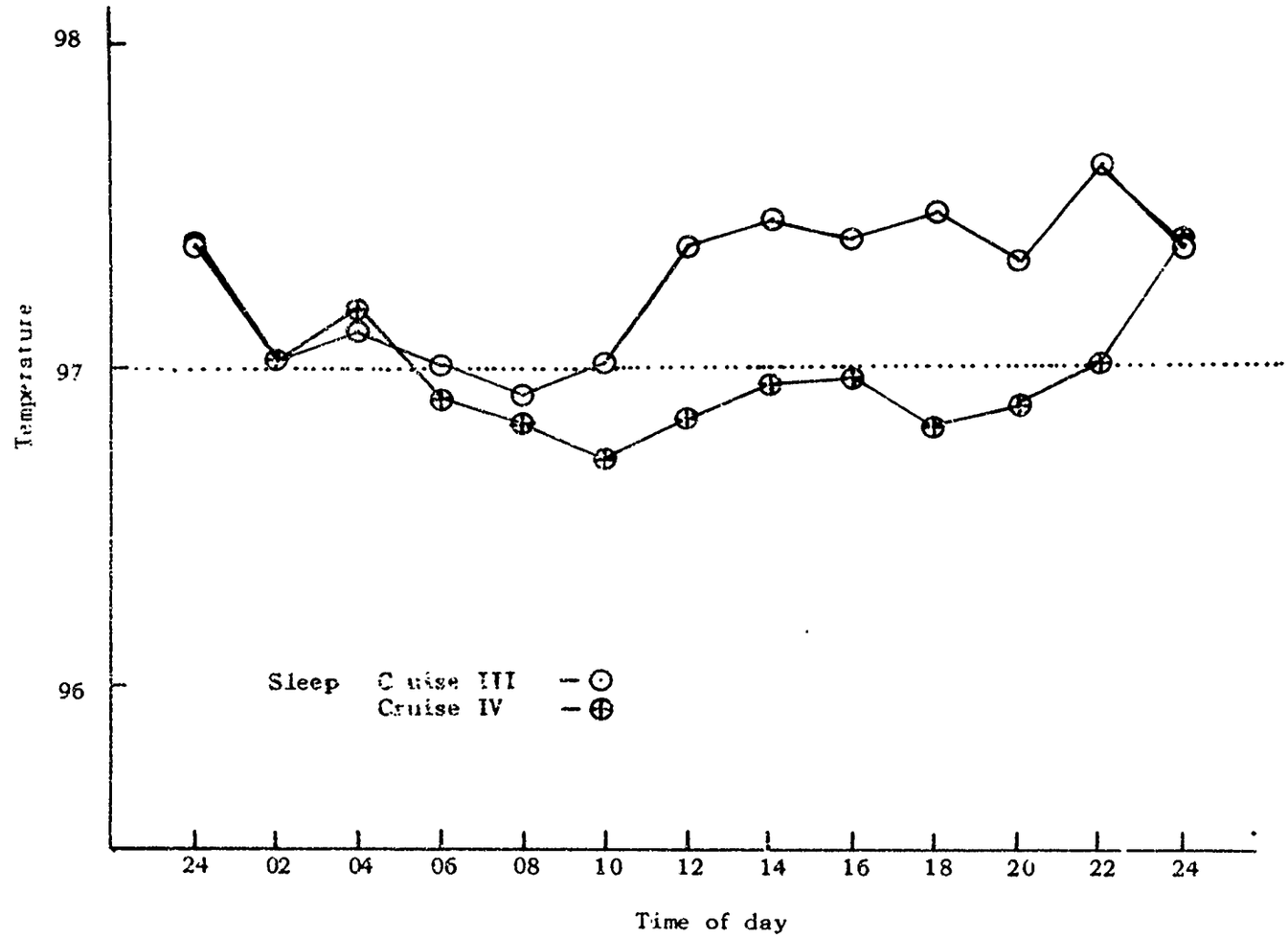


Figure 8 - Averages of temperatures taken during sleep on the final days of cruises III and IV On cruise III the present schedule (4 on - 8 off) was followed while the proposed schedule (3-3-2) was followed on cruise IV

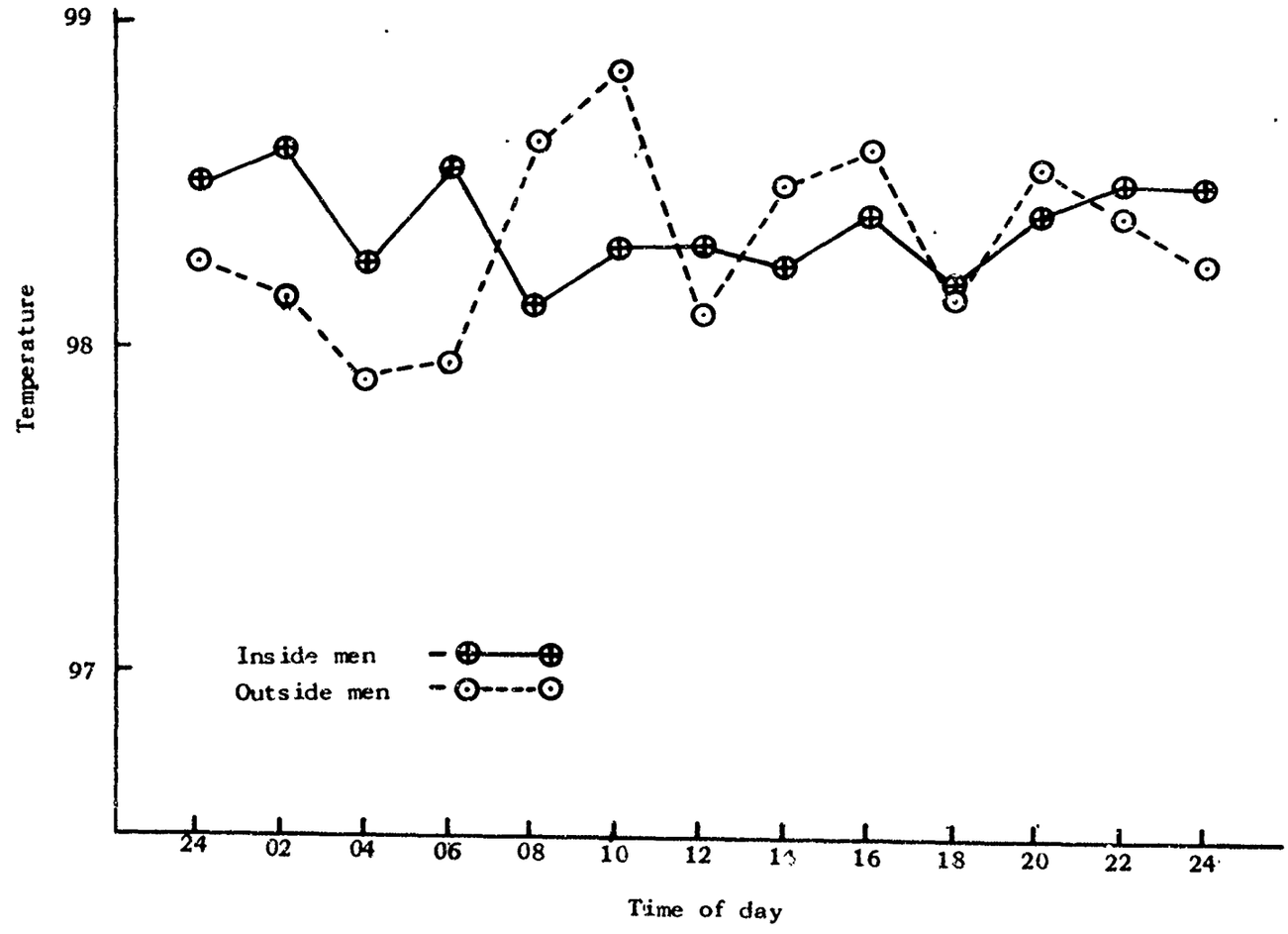


Figure 9.- Comparison of average temperatures of men on watch on look-out and helm (outside men) and men on engine room watch (inside men) during one week of cruise IV in which the proposed schedule (3-3-2) was followed.